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Histogram Equalization for Improving Quality of Low-resolution Ultrasonography Images

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Abstract

The current development of digital image processing techniques have been very rapid. Application of digital image processing both hardware and software are available with a variety of features as a form of superiority. Medical ultrasonography is one of the results of digital image processing technology. It is a kind of diagnostic imaging technique with ultrasonic that is used to produce images of internal organs and muscles, size, structure, and wound pathology, which makes this technique is useful for checking organ. However the images produced by low resolution ultrasonography device is not fully produce clear information. In this research we use histogram equalization to improve image quality. In this paper we emphasize on the comparison of the two methods in the histogram equalization, namely Enhance Contrast Using Histogram Equalization (ECHE) and Contrast-Limited Adaptive Histogram Equalization (CLAHE). The results showed that CLAHE give the best results, with the parameter value Nbins 256 and Distribution Rayleigh with MSE value 9744.80 and PSNR value 8.284150.

***Keywords**: Histogram equalization, ultrasonography image, ECHE, CLAHE, MSE, PNSR*

1. Introduction

Advances in science and technology today brings a tremendous impact in various fields including the health sector. One technology that brings great influence in the field of health is the emergence imaging machine that can capture virtually all electromagnetic signals from gamma to radio waves. This machine can work even if the imagery from sources that do not fit or can not be captured by the human eye. This causes digital image processing usefulness and have broad application. Medical ultrasonography (USG) is one result of digital image processing technology. This technology is a diagnostic imaging technique with ultra sound is used to produce images of internal organs and muscles, size, structure, and wound pathology, which makes this technique is useful for checking organ [1]. Ultrasound image is now growing rapidly. It first appeared, there are only two-dimensional ultrasound images (2D). Today, technology has evolved into a three-dimensional ultrasound image (3D) and four-dimensional ultrasound image (4D). Imagery obtained through ultrasound, sometimes have a quality loss may be the contrast range, geometric distortion, blurriness or noise [2]. Therefore, in order to obtain ultrasound images that clearly identified, then the image must be improved.

There are some researches that discuss the improvement of the quality of medical images. Some of thes are: Shet [3] discussed the effects of exposure reduction on image quality. He proposed a method to improve detector technology and image processing techniques and tailoring exposure to the exam type and patient body habitus. Cho [4] evaluated a method to maintain the optimal image quality in clinical practice for image quality management in a picture archiving and communication system (PACS) that uses typical technology for digital medical images. Mohanapriya [5] discussed about spatial domain enhancement techniques along with their algorithm and also analyzes their performance based on the image quality for medical images. Panetta [6] proposed a quantitative metric for measuring the image quality in order tselect the optimal operating parameters for the enhancement algorithms. Karthikeyan [7] proposed three techniques for edge enhancement, image enlargement and image fusion. All the algorithms have the common goal of improving the visual quality of ultrasonic images and are based wavelets and other image processing techniques. The proposed models were tested

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vigorously using various test images obtained and the experimental results proved that the proposed models produce significant improvement over the existing traditional systems. Lalotra [8] discussed about quality of fused image can be enhanced by using combination of Butterworth High Pass filter and Cross Bilateral filter. Vaezi [9] proposed a novel and effective semi-automatic method to improve the quality of 2D image segmentation process. Kumar [10] discussed about a novel, structured visual quality improvement mechanism based on daubechies (db) wavelet transform. In the proposed methodology, the segmentation of the ultrasound medical image is carried out with the help of active contour technique. Nagata [11] evaluated the radiation dose and image quality comparing low-dose CT colonography (CTC) reconstructed using different levels of iterative reconstruction techniques with routine-dose CTC reconstructed with filtered back projection. Gadallah [12] using double thresholding for image segmentation after denoising in Curvelet transform domain applied in hepatic abcessed. Kaur [13] discussed about segmentation algorithmshave been applied on Thyroid Scintigraphy and Ultrasound Images.

Chen [14] developed a fully-automated and efficient method for detecting contour of common carotid artery in the cross section view of two-dimensional B-mode sonography.They evaluated 130 ultrasound images from three healthy volunteers and thesegmentation results were compared to the boundaries outlined by an expert. Teng [15] using image segmentation to discover regions of interest (ROI) using self-organizing maps (SOM). They devise a two-stage SOM approach that can be used to precisely identify the dominant colors of a medical image and then segment it into several small regions. Becker [16] using an algorithm based on a 3D statistical shape model to segment the fetal cerebellum on 3D ultrasound volumes. This model is adjusted using an ad hoc objective function which is in turn optimized using the Nelder-Mead simplex algorithm. Kocer [17] measured the effecr of filters to automate segmentation of DDH ultrasound images in order to make it convenient for radiologic diagnosis.

Gupta [18] developed an automatic segmentation of SSP tendon ultrasound image to provide focused and more accurate diagnosis. The image processing techniques were employed for automatic segmentation of SSP tendon. The image processing techniques combines curvelet transform and mathematical concepts of logical and morphological operators along with area filtering. Huang [19] developed a fully automated (i.e. operator-independent) PS image segmentation forthe estimation of thyroid volume. Loizou [20] proposed the best performing method that can be used for the segmentation of the IMC and the atherosclerotic carotid plaque in ultrasound images and videos. Referring to the research that has been done, it seems that most of the research carried out for advanced medical facilities In our previous research [21-28] we also implemented image processing teqniques for improving medical images quality.

In this paper, we aim to explore the advantages of histogram equalization method for improving image quality in low-resolution ultrasonography images. Image histogram is described in a simple as a bar graph of the intensity of the pixels. Pixel intensity plotted along the x-axis and the number of appearances for each intensity represented on the y-axis. From a histogram can be determined relative frequency of occurrence (Relative) of intensity on that image. The histogram can also show many things about the brightness and contrast of an image. Therefore histogram is a valuable tool in image processing work either qualitatively and quantitatively [29].

2. Research Method

2.1. Data Acquisition

Data used in this research is the ultrasonography images obtained from general hospital “Prof. Margono Soekarjo” Purwokerto, Central Java Indonesia. Figure 1 shows an example of ultrasonography image that used in our research. In the original images, there is informations about patient’s name and hospital, medical records, etc.Therefore we need to crop this kind of information. Figure 2 shows the result of image after we cropped the information above.

 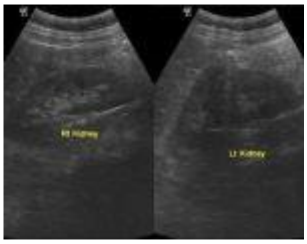

Figure 1. Original image Figure 2. Cropped image

2.2. Pre-processing Image

The first step in the pre-processing image is changing the original image which is an RGB image into gray scale image. In a grayscale image, each pixel has only one value in the form of gray scale. Starting with black at the lowest intensity level until the white color with the highest intensity level. The aim of converting RGB image to grayscale image is to simplify image model to do digital image processing. Figure 3 shows the result of grayscale image. The next stage is the stage of screening or filtering. A stage which is useful for reducing noise. In this research we use Median Filter because this filter has the ability to reduce noise very well. Figure 4 shows the result of median filter.

 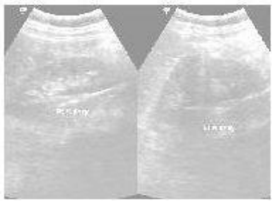

Figure 3. Grayscale image Figure 4. Median filter

2.3. Histogram Equalization

Histogram equalization is to change the image intensity values in order to make a uniform distribution of intensity in the whole image. Histogram equalization obtained by changing the degree of gray of a pixel (r) with the degree of gray new one (s) with a transformation function T, which in this case s=T (r). Where r can be recovered from the inverse transformation r s=T-1 (s) where, 0 ≤ s ≤ 1. Fo 0 ≤ ri ≤ 1 then 0 ≤ T (r) ≤ 1. This is to ensure consistent mapping on the range allowed values [29]. Histogram equalization process results will not be uniform or equal to the entire intensity. This technique can only redistribute the intensity distribution of the initial histogram. If the initial histogram has several peaks and valleys of the histogram equalization results will remain has peaks and valleys. However, the peaks and valleys that shifted. Histogram equalization results will be disseminated. The purpose of histogram equalization is to obtain equitable spread of the histogram so that each degree of gray has a relatively equal number of pixels. Because histogram expressed chance pixels with a certain degree of gray, the formula calculates the histogram flattening shown in Equation 1.

$$P_r(r_k) = \frac{n_k}{n} \quad (1)$$

In this case $r_k = \frac{K}{L-1}, 0 \leq k \leq L-1$

Histogram equalization method that will be used in this research are as follows [29]:

a. Enhance Contrast Using Histogram Equalization (ECHE)

This method increases the image contrast by changing the values in the image intensity, or the values in the colormap of an indexed image, so that the histogram of the output image with histogram determined approach. If using the specifications defined histogram (hgram) then the transformation T in the form of a grayscale will be minimal as shown in equation 2.

$$|c_1(T(k))-c_0(k)| \quad (2)$$

Where in, c_0 is the cumulative histogram A, c1 is a cumulative total intensity hgram for all k. If not using hgram, then hgram considered flat.

b. Contrast Limited Adaptive Histogram Equalization (CLAHE)

Adaptive histogram equalization is basically the same as ordinary histogram equalization. It's just an adaptive histogram equalization, the image is divided into blocks (sub-image) of size n x n, and then each block histogram equalization process is carried out. The block size (n) can vary and each block size will give different results. Each block can overlap some pixels in other blocks when combined using bilinear interpolation to eliminate artificially induced boundaries. Contrast, especially in homogeneous areas, can be limited in order to avoid noise that may be present in the image.

This research will generate 264 ultrasonography images which will be analyzed derived from 6 sample images. In ECHE method produces 30 images while CLAHE produce 234 images as shown in Table 1.

Tabel 1. The Parameters and Values Used

Method	Values number of Parameter 1	Values number of Parameter 2	Image number	Number of result image
ECHE	5 values (5, 10, 50, 100, 200)	-	6	5 x 6=30
CLAHE	ClipLimit 3 values : (0.01, 0.5, 1)	Distribution 3 values: (*uniform, rayleigh, exponential*)	6	3 x 3 x 6=54
	NumTiles 3 values: ([3 3], [8 8], [16 16])	Distribution 3 values: (*uniform, rayleigh, exponential*)	6	3 x 3 x 6=54
	Nbins 3 values: (100, 175, 256)	Distribution 3 values: (*uniform, rayleigh, exponential*))	6	3 x 3 x 6=54
	Range 2 values: (original, full)	Distribution 3 values: (*uniform, rayleigh, exponential*)	6	2 x 3 x 6=36
	Alpha 3 values: (0.2, 0.4, 0.8)	Distribution 2 values: (rayleigh, exponential)	6	3 x 2 x 6=36
Total Number				264

3. Results and Discussion

Based on observational data from the image generated by digital image processing such as histogram equalization, it can be observed that from each image that is expressed visually nice when that image can be used to diagnose patients. Criteria for good and not determined by medical practitioners in general hospital “Prof. Margono Soekarjo” Purwokerto, Central Java, Indonesia. The image of the identified clearly marked with a tick (√) on the contrary, the image does not provide the information marked with a dash (-). So also with contrast and sharpness with three categories: low, medium, and high.

In addition to visually, the parameters of success can also be seen on the MSE and PSNR. Peak Signal to Noise Ratio (PSNR) is the ratio between the maximum values of the signal measured by the amount of noise that affects the signals. PSNR is usually measured in decibels. In this research, PSNR is used to compare the image quality before and after histogram equalization. Table 2 to Table 5 described the results analysis of ECHE method.

According to Table 2 and Table 3, visually the threshold value-10-200, producing images that are relatively similar, but have different histograms. On the threshold value-5, the image is less clear because at least the grouping of grades of gray. If using a threshold value-2 will produce a binary image. Overall image is too dark on this method.

Table 2. Performance of ECHE Method

No	Threshold	Type of testing image (abdominal)					
		Image					
		1	2	3	4	5	6
1.	5	-	-	-	-	-	-
2.	10	√	√	√	√	√	√
3.	50	√	√	√	√	√	√
4.	100	√	√	√	√	√	√
5.	200	√	√	√	√	√	√

Table 3. Contrast and Sharpness of ECHE Method

No	Threshold	Type of testing image (abdominal)											
		Contrast						Sharpness					
		Low		Medium		High		Low		Medium		High	
		C1	C3	C1	C3	C1	C3	C1	C3	C1	C3	C1	C3
1.	5	√	-	-	-	-	√	-	-	-	-	√	√
2.	10	√	-	-	-	-	√	-	-	√	-	-	√
3.	50	√	-	-	-	-	√	√	-	-	-	-	√
4.	100	√	-	-	-	-	√	-	-	√	-	-	√
5.	200	√	√	-	-	-	-	-	√	√	-	-	-

Table 4. MSE Values of ECHE Method

No	Threshold	Type of testing image (abdominal)					
		Image					
		1	2	3	4	5	6
1.	5	10982.9	11350.1	10748.3	11167.4	11246.4	12639.7
2.	10	9664.7	10163.7	9355.7	9889.9	10156.3	11346.1
3.	50	8920.3	9482.2	8570.5	9166.5	9555.9	10630.7
4.	100	8862.6	9415.3	8516.6	9062.4	9506.3	10566.4
5.	200	8795.0	9372.5	8443.5	9016.8	9465.3	10517.8

Table 5. PNSR Values of ECHE Method

No	Threshold	Type of testing image (abdominal)					
		Image					
		1	2	3	4	5	6
1.	5	7.75764	7.61480	7.85141	7.68528	7.65466	7.14744
2.	10	8.31288	8.09429	8.45403	8.21285	8.09745	7.61635
3.	50	8.66099	8.39569	8.83471	8.54273	8.36207	7.89917
4.	100	8.68918	8.42645	8.86212	8.59233	8.38468	7.92551
5.	200	8.72244	8.44620	8.89956	8.61425	8.40343	7.94556

According to Table 4 and Table 5, the results of images tested, the MSE will decrease when the threshold value is enlarged. While the value of PSNR will be even greater when the threshold value is enlarged. Lowest MSE value, and the highest PSNR is when using a threshold of 200. This is because enlarge the threshold in the ECHE method as well as enlarge the range of gray values. Table 6 to Table 25 described the results analysis of CLAHE method.

Table 6. Performance of CLAHE Method (ClipLimit & Distribution)

No.	Parameter Values		Type of testing image (abdominal)					
	Clip Limit	Distribution	Image					
			1	2	3	4	5	6
1.	0.01	uniform	√	√	√	√	√	√
2.	0.01	rayleigh	√	√	√	√	-	√
3.	0.01	exponential	√	-	√	√	√	√
4.	0.5	uniform	-	-	-	-	-	-
5.	0.5	rayleigh	-	-	-	-	-	-
6.	0.5	exponential	-	-	-	-	-	-
7.	1	uniform	-	-	-	-	-	-
8.	1	rayleigh	-	-	-	-	-	-
9.	1	exponential	-	-	-	-	-	-

Table 7. Contrast and Sharpness of CLAHE Method (ClipLimit & Distribution)

No.	Parameter Values		Type of testing image (abdominal)											
	Clip Limit	Distribution	Contrast						Sharpness					
			Low		Medium		High		Low		Medium		High	
			C1	C3	C1	C3	C1	C3	C1	C3	C1	C3	C1	C3
1.	0.01	uniform	√	√	-	-	-	-	√	√	-	-	-	-
2.	0.01	rayleigh	√	-	-	√	-	-	√	√	-	-	-	-
3.	0.01	exponential	√	-	-	√	-	-	√	√	-	-	-	-
4.	0.5	uniform	-	-	√	√	-	-	-	√	-	√	√	-
5.	0.5	rayleigh	--	-	√	-	-	√	-	-	√	√	-	-
6.	0.5	exponential	-	-	√	-	-	√	-	-	√	√	-	-
7.	1	uniform	-	-	-	-	√	√	-	-	√	-	-	√
8.	1	rayleigh	-	-	√	-	-	√	-	-	-	√-	√	-
9.	1	exponential	-	-	√	-	-	√	-	-	-	-	√	√

According to Table 6 and Table 7, visually using parameter 0:01 ClipLimit valuable and Distribution parameter with a value of uniform, Rayleigh, or exponential, producing images that are relatively the same, but have different histograms. By raising the value of the parameter ClipLimit of 0.5 and 1 the results were less clear because the image of the object and the background becomes mixed. The level of contrast and sharpness of the image 1 (C1) and the image 3 (C3) is different. The addition of the value of the parameter ClipLimit result in image contrast and sharpness increases. While the use of the Distribution parameters also affects contrast and sharpness of the image produced.

Table 8. MSE Values of CLAHE Method (ClipLimit & Distribution)

No.	Parameter Values		Type of testing image (abdominal)					
	CL	Dist	Image					
			1	2	3	4	5	6
1.	0.01	uni	13858.3	13849.2	13713.1	15512.3	13567.1	13606.8
2.	0.01	ray	9633.8	9636.2	9435.0	11005.5	9435.1	9327.1
3.	0.01	exp	11628.5	11551.8	11495.2	13254.3	11283.7	11344.1
4.	0.5	uni	10989.2	11468.7	10309.6	12343.5	11142.5	10822.1
5.	0.5	ray	8400.9	8709.0	7844.8	9656.5	8506.6	8173.7
6.	0.5	exp	9562.7	9978.8	8964.0	10953.2	9666.0	9398.8
7.	1	uni	11422.6	11905.5	10623.0	12656.5	11604.4	11550.6
8.	1	ray	8730.5	9042.8	8075.3	9886.4	8877.2	8809.4
9.	1	exp	10005.0	10424.2	9283.7	11272.3	8877.2	10167.8

Table 9. PSNR Values of CLAHE Method (ClipLimit & Distribution)

No.	Parameter Values		Type of testing image (abdominal)					
	CL	Dist	Image					
			1	2	3	4	5	6
1.	0.01	uni	6.74771	6.75055	6.79345	6.25803	6.83900	6.82723
2.	0.01	ray	8.32682	8.32573	8.41736	7.74869	8.41731	8.46733
3.	0.01	exp	7.50955	7.53829	7.55962	6.94123	7.64028	7.61708
4.	0.5	uni	7.75515	7.56966	8.03240	7.25041	7.69496	7.82169
5.	0.5	ray	8.92153	8.76507	9.21895	8.31660	8.86722	9.04057
6.	0.5	exp	8.35898	8.17400	8.63974	7.76939	8.31229	8.43405
7.	1	uni	7.58715	7.40730	7.90234	7.14167	7.51857	7.53874
8.	1	ray	8.75439	8.60173	9.09319	8.21440	8.68203	8.71533
9.	1	exp	8.16263	7.98437	8.48758	7.64468	8.68203	8.09253

According to Table 8 and Table 9, in the calculation of the value of MSE and PSNR of CLAHE method with parameter ClipLimit and Distribution, the MSE is spread over a range of 7844.8 - 15512.3. While PNSR in the range of 6.25803 - 9.21895. Parameter distribution also affect the value of MSE and PSNR.

Table 10. Performance of CLAHE Method (NumTiles & Distribution)

No.	Parameter Values		Type of testing image (abdominal)					
	NumTiles	Distribution	Image					
			1	2	3	4	5	6
1.	[3 3]	uniform	√	√	√	√	-	√
2.	[3 3]	rayleigh	√	√	√	√	-	-
3.	[3 3]	exponential	√	-	√	√	√	√
4.	[8 8]	uniform	√	√	√	√	√	√
5.	[8 8]	rayleigh	√	√	√	√	√	√
6.	[8 8]	exponential	√	√	√	√	√	√
7.	[16 16]	uniform	-	-	-	-	-	-
8.	[16 16]	rayleigh	-	-	-	-	-	-
9.	[16 16]	exponential	-	-	-	-	-	-

Table 11. Contrast and Sharpness of CLAHE Method (NumTiles & Distribution)

No.	Parameter Values		Type of testing image (abdominal)											
	NumTiles	Distribution	Contrast						Sharpness					
			Low		Medium		High		Low		Medium		High	
			C1	C3	C1	C3	C1	C3	C1	C3	C1	C3	C1	C3
1.	[3 3]	uniform	√	-	-	√	-	-	-	-	√	√	-	-
2.	[3 3]	rayleigh	√	-	-	√	-	-	√	√	-	-	-	-
3.	[3 3]	exponential	√	√-	-	-	-	-	-	-	√	√	-	-
4.	[8 8]	uniform	√	√	-	-	-	-	-	-	√	√	-	-
5.	[8 8]	rayleigh	√	√	-	-	-	-	√	-	-	√	-	-
6.	[8 8]	exponential	√	-	-	√	-	-	√	-	-	√	-	-
7.	[16 16]	uniform	√	-	-	√	-	-	-	-	√	-	-	√
8.	[16 16]	rayleigh	√	-	-	√	-	-	√	-	-	√	-	-
9.	[16 16]	exponential	√	-	-	√	-	-	√	-	-	√	-	-

According to Table 10 and Table 11, if the value on NumTiles worth [16, 16] the resulting image is not good because it is too small kernel used or shared image too much. For value [3 3] and [8 8] visually produces a better image than without equalization. By using the parameters of contrast and sharpness, image 1 (C1) and the image 3 (C3) on average result in images with low contrast and sharpness.

Table 12. MSE Values of CLAHE Method (NumTiles & Distribution)

No.	Parameter Values		Type of testing image (abdominal)					
	NT	Dist	Image					
			1	2	3	4	5	6
1.	[3 3]	uni	11153.4	12366.3	11468.1	11918.3	13451.3	9921.3
2.	[3 3]	ray	7981.7	9058.1	8295.3	8539.7	9940.6	7165.7
3.	[3 3]	exp	9256.3	10471.7	9687.4	9938.4	11515.9	8141.9
4.	[8 8]	uni	13858.0	14922.5	13870.1	14483.8	15475.3	13606.0
5.	[8 8]	ray	9633.6	10607.3	9736.1	10055.4	11054.8	9327.3
6.	[8 8]	exp	11630.5	12695.5	11754.5	12166.7	13192.0	11339.0
7.	[16 16]	uni	16276.2	17269.5	16063.0	16932.8	17833.4	15877.7
8.	[16 16]	ray	11080.4	11998.4	11019.1	11529.4	12450.0	10667.4
9.	[16 16]	exp	13837.5	14828.7	13732.3	14419.1	15345.7	13416.8

Table 13. PSNR Values of CLAHE Method (NumTiles & Distribution)

No.	Parameter Values		Type of testing image (abdominal)					
	NT	Dist	Image					
			1	2	3	4	5	6
1.	[3 3]	uni	7.69072	7.2424	7.56987	7.40267	6.87716	8.19909
2.	[3 3]	ray	9.14384	8.59442	8.97646	8.85034	8.19067	9.61219
3.	[3 3]	exp	8.50039	7.96464	8.30272	8.19160	7.55182	9.05750
4.	[8 8]	uni	6.74778	6.42638	6.74400	6.55596	6.26840	6.82749
5.	[8 8]	ray	8.32690	7.90876	8.28092	8.14081	7.72929	8.46720
6.	[8 8]	exp	7.50880	7.12829	7.46277	7.31307	6.96171	7.61904
7.	[16 16]	uni	6.04927	5.79199	6.10654	5.87750	5.65246	6.15692
8.	[16 16]	ray	7.71926	7.37355	7.74334	7.54674	7.21310	7.88423
9.	[16 16]	exp	6.75421	6.45378	6.78737	6.57542	6.30494	6.88830

According to Table 12 and Table 13, the results of the calculation of MSE and PSNR in the image of the smallest MSE value obtained when NumTiles parameter-value [3 3], the largest PSNR values were also obtained when the parameter NumTiles worth [3 3] with the Distribution Rayleigh or exponential.

Table 14. Performance of CLAHE Method (Nbins & Distribution)

No.	Parameter Values		Type of testing image (abdominal)					
	Nbins	Distribution	Image					
			1	2	3	4	5	6
1.	100	uniform	-	-	-	-	-	-
2.	100	rayleigh	√	-	√	√	-	√
3.	100	exponential	-	-	-	-	-	-
4.	175	uniform	-	-	-	-	-	-
5.	175	rayleigh	√	√	√	√	√	√
6.	175	exponential	√	√	√	√	√	√
7.	256	uniform	√	√	√	√	√	√
8.	256	rayleigh	√	√	√	√	√	√
9.	256	exponential	√	√	√	√	√	√

Table 15. Contrast and Sharpness of CLAHE Method (Nbins & Distribution)

No.	Parameter Values		Type of testing image (abdominal)											
	Nbins	Distribution	Contrast						Sharpness					
			Low		Medium		High		Low		Medium		High	
			C1	C3	C1	C3	C1	C3	C1	C3	C1	C3	C1	C3
1.	100	uniform	√	√	-	-	-	-	√	-	-	√	-	-
2.	100	rayleigh	√	√	-	-	-	-	-	-	√	√	-	-
3.	100	exponential	√		-	√	-	-	-	√	√	-	-	-
4.	175	uniform	√	√	-	-	-	-	-	-	√	√	-	-
5.	175	rayleigh	√	√	-	-	-	-	√	√	-	-	-	-
6.	175	exponential	-	-	√	√	-	-	-	-	√	√	-	-
7.	256	uniform	-	-	√	√	-	-	-	-	√	√	-	-
8.	256	rayleigh	-	-	√	√	-	-	-	-	√	√	-	-
9.	256	exponential	-	-	√	√	-	-	√	-	-	√	-	-

According to Table 14 and Table 15, in combination Nbins parameters and Distribution image is not good when the value Nbins 100, but when it was increased to 256 resulting in a better image. In the assessment results based on image contrast and sharpness in image 1 (C1) and the image 3 (C3) never touch the category of high contrast and sharpness. The contrast value will be higher when the value of the parameter Nbins enlarged, while the average value of sharpness in middle category.

Table 16. MSE Values of CLAHE Method (Nbins & Distribution)

No.	Parameter Values		Type of testing image (abdominal)					
	Nb	Dist	Image					
			1	2	3	4	5	6
1.	100	uni	17381.6	17204.2	17509.5	19250.2	17406.2	17594.4
2.	100	ray	11712.4	11593.3	11696.3	13234.0	11642.9	11674.0
3.	100	exp	14863.2	14612.2	15031.9	13234.0	14784.0	15038.2
4.	175	uni	15293.4	15257.8	15324.6	17094.1	15223.7	15335.6
5.	175	ray	10459.3	10437.1	10365.4	11916.8	10368.7	10314.7
6.	175	exp	12904.1	12817.4	12966.5	14698.7	12759.1	12913.6
7.	256	uni	13861.8	13848.2	13709.3	15508.4	13586.8	13586.3
8.	256	ray	9636.9	9634.1	9432.4	11002.7	9446.8	9315.9
9.	256	exp	11633.2	11552.0	11491.3	13250.2	11302.0	11323.2

Table 17. PSNR Values of CLAHE Method (Nbins & Distribution)

No.	Parameter Values		Type of testing image (abdominal)					
			Image					
	Nb	Dist	1	2	3	4	5	6
1.	100	uni	5.76391	5.80847	5.73206	5.32046	5.75775	5.71106
2.	100	ray	7.47834	7.52272	7.48432	6.94788	7.50419	7.49261
3.	100	exp	6.44368	6.51765	6.39466	5.92799	6.46688	6.39285
4.	175	uni	6.31976	6.32988	6.31091	5.83634	6.33961	6.30778
5.	175	ray	7.96976	7.97902	8.00894	7.40321	8.00757	8.03022
6.	175	exp	7.05754	7.08679	7.03656	6.49201	7.10661	7.05431
7.	256	uni	6.74659	6.75087	6.79463	6.25912	6.83364	6.83378
8.	256	ray	8.32541	8.32666	8.41858	7.74980	8.41192	8.47253
9.	256	exp	7.50781	7.53822	7.56109	6.94257	7.63324	7.62510

According to Table 16 and Table 17, the smallest MSE value obtained when Nbins worth 256, as well as the largest PSNR value. The average value of MSE greater when the value Nbins minimized and PSNR greater when the enlarged Nbins value.

Table 18. Performance of CLAHE Method (Range & Distribution)

No.	Parameter Values		Type of testing image (abdominal)					
	Range	Distribution	Image					
			1	2	3	4	5	6
1.	original	uniform	√	-	√	√	-	√
2.	original	rayleigh	√	√	√	√	√	√
3.	original	exponential	√	√	√	√	√	√
4.	full	uniform	√	√	√	√	-	√
5.	full	rayleigh	√	-	√	√	√	√
6.	full	exponential	√	√	√	√	√	√

Table 19. Contrast and Sharpness of CLAHE Method (Range & Distribution)

No.	Parameter Values		Type of testing image (abdominal)											
	Range	Distribution	Contrast						Sharpness					
			Low		Medium		High		Low		Medium		High	
			C1	C3	C1	C3	C1	C3	C1	C3	C1	C3	C1	C3
1.	original	uniform	-	-	√	√	-	-	√	-	-	√	-	-
2.	original	rayleigh	-	-	√	√	-	-	-	-	√	√	-	-
3.	original	exponential	-	-	√	√	-	-	-	-	√	√	-	-
4.	full	uniform	-	-	√	√	-	-	-	-	√	√	-	-
5.	full	rayleigh	√	-	-	-	-	√	-	-	√	√	-	-
6.	full	exponential	-	-	√	√	-	-	-	-	√	√	-	-

According to Table 18 and Table 19, The results of histogram equalization with a combination of parameters Range and Distribution almost all produce relatively the same image, using either the original or full parameter combined with uniform parameters, rayleigh, and exponential. For the assessment of the parameters in the image contrast and sharpness 1 (C1) and the image 3 (C3) on average tends to have the contrast and sharpness are moderate.

Table 20. MSE Values of CLAHE Method (Range & Distribution)

No.	Parameter Values		Type of testing image (abdominal)					
			Image					
	Rng	Dist	1	2	3	4	5	6
1.	ori	uni	14785.1	15106.0	13720.8	15519.2	15929.9	15097.5
2.	ori	ray	10359.4	10599.8	9442.1	11012.4	11439.0	10741.7
3.	ori	exp	12581.3	12839.1	11503.4	13261.9	13657.1	12907.5
4.	full	uni	14785.1	15106.0	13720.8	15519.2	15929.9	15097.5
5.	full	ray	10359.4	10599.8	9442.1	11012.4	11439.0	10741.7
6.	full	exp	12581.3	12839.1	11503.4	13261.9	13657.1	12907.5

Table 21. PSNR Values of CLAHE Method (Range & Distribution)

No.	Parameter Values		Type of testing image (abdominal)					
			Image					
	Rng	Dist	1	2	3	4	5	6
1.	ori	uni	6.46656	6.37330	6.79101	6.25611	6.14266	6.37575
2.	ori	ray	8.01144	7.91183	8.41410	7.74600	7.58092	7.85405
3.	ori	exp	7.16753	7.07946	7.55653	6.93873	6.81122	7.05636
4.	full	uni	6.46656	6.37330	6.79101	6.25611	6.14266	6.37570
5.	full	ray	8.01144	7.91183	8.41410	7.74600	7.58092	7.85405
6.	full	exp	7.16753	7.07946	7.55653	6.93873	6.81122	7.05636

According to Table 20 and Table 21, the results of MSE and PSNR calculation methods CLAHE the parameter range and distribution to produce the highest MSE value and the lowest PSNR in the Distribution uniform. In Rayleigh produce the same MSE and PSNR both original and full.

Table 22. Performance of CLAHE Method (Alpha & Distribution)

No.	Parameter Values		Type of testing image (abdominal)					
			Image					
	Alpha	Distribution	1	2	3	4	5	6
1.	0.2	rayleigh	-	-	-	-	-	-
2.	0.2	exponential	√	-	√	√	-	√
3.	0.4	rayleigh	√	√	√	√	√	√
4.	0.4	exponential	√	√	√	√	√	√
5.	0.8	rayleigh	-	-	-	-	-	-
6.	0.8	exponential	√	√	√	√	√	√

Table 23. Contrast and Sharpness of CLAHE Method (Alpha & Distribution)

No.	Parameter Values		Type of testing image (abdominal)											
			Contrast						Sharpness					
	Alpha	Distribution	Low		Medium		High		Low		Medium		High	
			C1	C3	C1	C3	C1	C3	C1	C3	C1	C3	C1	C3
1.	0.2	rayleigh	√	-	-	-	-	√	√	√		-	-	-
2.	0.2	exponential	-	-	√	-	-	√	-	-	√	√	-	-
3.	0.4	rayleigh	-	-	√	√	-	-	-	-	√	√	-	-
4.	0.4	exponential	-	-	√	√	-	-	-	-	√	√	-	-
5.	0.8	rayleigh	-	√	√	-	-	-	-	√	√		-	-
6.	0.8	exponential	-	-	√	√	-	-	-	-	√	√	-	-

According to Table 22 and Table 23, the combination of Alpha and Distribution parameters of the resulting image is not good, the Alpha worth 0.2 and 0.8 with rayleigh Distribution. The image becomes too dim to the value of 0.2, too light on the value of 0.8. While the remaining combinations produce a good image. In contrast and sharpness assessment, image 1 (C1) and the image 3 (C3), have an average contrast and sharpness with moderate categories. But there are some who have the contrast and sharpness of low and high as the value of Alpha 0.2 and 0.8.

Table 24. MSE Values of CLAHE Method (Alpha & Distribution)

No.	Parameter Values		Type of testing image (abdominal)					
			Image					
	Alp	Dist	1	2	3	4	5	6
1.	0.2	ray	1462.6	2138.0	1389.9	2328.4	1065.0	1364.1
2.	0.2	exp	12730.2	13794.8	12602.6	14381.6	12402.7	12446.1
3.	0.4	ray	9636.6	10610.0	9439.2	11008.8	9427.6	9415.3
4.	0.4	exp	11630.4	12694.6	11504.4	13262.2	11275.7	11384.6
5.	0.8	ray	19716.2	20742.4	19458.3	21273.6	19776.4	19330.1
6.	0.8	exp	9552.7	10612.0	9432.9	11139.5	9157.3	9387.7

Table 25. PSNR Values of CLAHE Method (Alpha & Distribution)

No.	Parameter Values		Type of testing image (abdominal)					
			Image					
	Alp	Dist	1	2	3	4	5	6
1.	0.2	ray	16.5134	14.8646	16.7347	14.4942	17.8910	16.8163
2.	0.2	exp	7.1164	6.7676	7.1601	6.5867	7.2296	7.2144
3.	0.4	ray	8.3255	7.9076	8.4154	7.7474	8.4207	8.4264
4.	0.4	exp	7.5088	7.1286	7.5561	6.9386	7.6433	7.6016
5.	0.8	ray	5.2165	4.9962	5.2737	4.8863	5.2033	5.3024
6.	0.8	exp	8.3635	7.9068	8.4183	7.6961	8.5470	8.4391

According to Table 24 and Table 25, MSE and PSNR calculation methods CLAHE with parameters Alpha and Distribution produces the smallest MSE value and the largest PNSR on Alpha 0.2, but in terms of the visual side, the image is too dark because of the histogram are concentrated in the left area. According to the results as described in all Tables above, we could make a comparison between ECHE method and CLAHE method as shown in Table 26.

Table 26. Comparison between ECHE and CLAHE method

No	Parameter Value		Average MSE	Average PSNR	VIsually	Medium Contrast		Medium Sharpnes s	
						C1	C3	C1	C3
1.	ECHE Thrshld 200		9868.48	8.105240	6/6 x 100%=100%	-	-	√	-
	CLAHE								
2.	1	ray	8903.60	8.676845	0/6 x 100%=0	√	-	-	√
3.	[3 3]	ray	8496.85	8.894653	4/6 x 100%=66,6%	-	√	-	-
4.	256	ray	9744.80	8.284150	6/6 x 100%=100%	√	√	√	√
5.	ori	ray	10599.07	7.919723	6/6 x 100%=100%	√	√	√	√
6.	full	ray	10599.07	7.919723	6/6 x 100%=100%	-	-	√	√
7.	0.2	ray	1624.67	16.219033	0/6 x 100%=0%	-	-	-	-

4. Conclusions

According to our results as discussed above, we conclude that (i) histogram equalization on a 2D image of Medical Ultrasound (USG) can improve image quality and make it easier for medical practitioners diagnose the disease. (ii) By comparing two methods of histogram equalization, concluded CLAHE method is better than the ECHE method. (iii) The best combination in CLAHE method is, using parameter Nbins worth 256 and Distribution Rayleigh with MSE value is 9744.80 and PSNR value is 8.284150.

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